Field volatility of Dicamba BAPMA

Report:	MRID 51049003. Toth, B.N. Off-target Movement Assessment of a Spray Solution Containing BAS 183 22 H and a Tank Mix Partner – Mississippi. Unpublished study performed by Stone Environmental, Inc., Montpelier, Vermont; Eurofins EAG Agroscience, LLC, Columbia, Missouri; and AGVISE Laboratories, Northwood, North Dakota; sponsored and submitted by BASF Corporation, Research Triangle Park, North Carolina. Stone Study ID: 19-038-B. Eurofins Study ID: 89022. BASF Study ID: 878378. Agvise Study ID: 19-97 and 19-1188. Experiment initiation June 22, 2019 and completion July 16, 2019 (p. 6). Study and Report completion January 28, 2020.
Document No.:	MRID 51049003
Guideline:	OCSPP 835.8100 and 840.1200
Statements:	The study was completed in compliance with US EPA FIFRA GLP standards (40 CFR Part 160) with the exception of test site observations, pesticide and crop history, soil taxonomy, application summary and spray rate data, and study weather data (p. 3). Signed and dated Data Confidentiality, GLP Compliance, Quality Assurance, and Authenticity Certification statements were provided (pp. 2-4 and 7).
Classification:	This study is **supplemental**. Monitoring started after the conclusion of application. A storm event occurred on Day 2, affecting the volatility and plant effects measurements. The addition of an approved buffering agent was included in the tank mix but was not included in the protocol reviewed by EPA. This adds uncertainty to the volatile flux rates, as the buffering agent may have reduced volatility of dicamba.
PC Code:	100094

Final EPA Reviewer:	Chuck Peck Senior Fate Scientist	Signature: Chuck Peck Date: 2020.10.24 22:26:11 -04'00'
Final EPA Reviewer:	Frank T. Farruggia, Ph.D. Senior Effects Scientist	Signature: Date: 2020.10.25 12:26:57 -04'00'
CDM/CSS-Dynamac JV Reviewers:	Dan Hunt, M.S. Environmental Scientist	Signature: Dan Hunt Date: 4/13/20
	Richard Lester Environmental Scientist	Signature: Richard R Lester Date: 4/13/20

This Data Evaluation Record may have been altered by the Environmental Fate and Effects Division subsequent to signing by CDM/CSS-Dynamac JV personnel. The CDM/CSS-Dynamac Joint Venture role does not include establishing Agency policies.

Executive Summary

Field volatilization of dicamba formulation BAS 183 22 H (dicamba in the form of its N,N-Bis-(3-aminopropyl)methylamine (BAPMA) salt) when tank mixed with Roundup PowerMax® and Intact™ (polyethylene glycol, choline chloride, and guar gum) was examined from a single dicamba-tolerant soybean-cropped test plot surrounded by non-dicamba tolerant soybean in Washington County, Mississippi. Vapor sampling and spray drift deposition sampling were conducted for *ca.* 168 hours following application. The products were applied at a nominal rate of 0.5 lbs. a.e./A. The study also examined off-target movement due to volatility and spray drift and resulting impacts to non-target plants. A control plot was established upwind of the test plot for plant effects. No control plot was established for field volatilization measurements.

Air temperatures, surface soil temperatures, and relative humidity the day of application (6/22/19) ranged from 24.8-33.8°C (76.6-92.8°F), 20.1-36.8°C (68.2-98.2°F), and 57-95%, respectively. Air temperatures, surface soil temperatures, and relative humidity ranged from 19.4-35°C (66.9-95°F), 20.4-40.5°C (68.7-105°F), and 52-100%, respectively, 1 to 7 days after application. A thunderstorm occurred during the 24 to 48-hour post-application sampling period, with heavy rain (4.59 inches), such that volatility and deposition samples were either not collected, or were non-detect for periods 4-8 after application, resulting in uncertainty during these sampling periods.

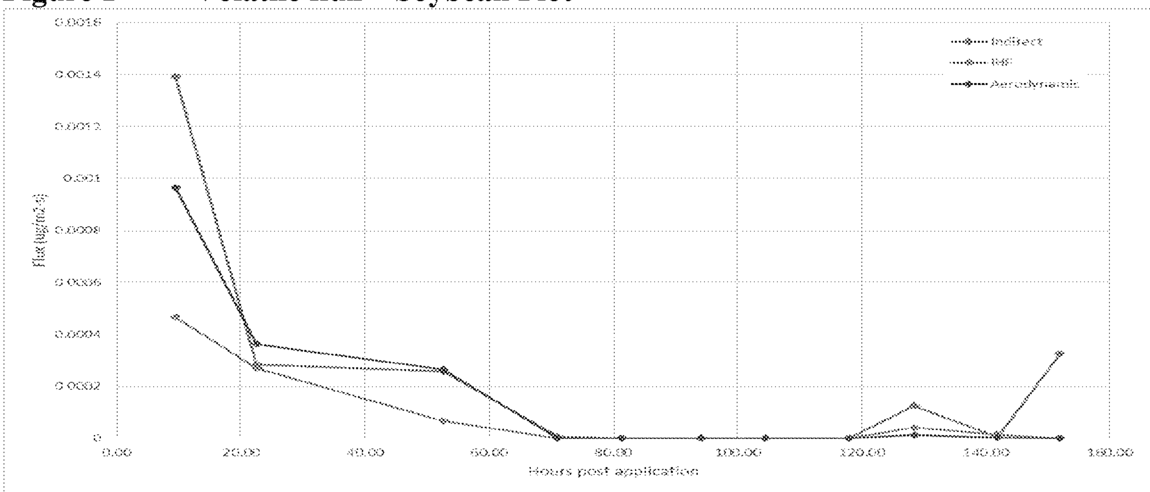
Under field conditions at the test plot, based on calculations using the Indirect method, study authors estimated a peak volatile flux rate of 0.001392 $\mu g/m^2 \cdot s$ was measured accounting for 0.093% of the applied dicamba observed 0.6 to 11.3 hours post-application, with a total of 0.307% of dicamba volatilized and was lost from the field by the end of the study. The reviewer confirmed the peak flux rate and estimated that the total of amount of dicamba volatilized and lost from the field by the end of the study was 0.215%. Peak and secondary peak volatile flux rates occurred during warm daytime hours.

Under field conditions at the test plot, based on calculations using the Integrated Horizontal Flux method, study authors estimated a peak volatile flux rate of 0.000897 $\mu g/m^2 \cdot s$, accounting for 0.055% of the applied dicamba observed 1.2 to 10.7 hours post-application. By the end of the study, a total of 0.097% of dicamba volatilized and was lost from the field. The reviewer estimated a peak flux rate of 0.000466 $\mu g/m^2 \cdot s$, accounting for 0.028% of the applied dicamba observed 1.2 to 10.7 hours post-application, and a total of 0.070% of dicamba volatilized and was lost from the field by the end of the study. Peak and secondary peak volatile flux rates occurred during warm daytime hours.

Under field conditions at the test plot, based on calculations using the Aerodynamic method, study authors estimated a peak volatile flux rate of 0.000620 $\mu g/m^2 \cdot s$, accounting for 0.038% of the applied dicamba observed 1.2 to 10.7 hours post-application. By the end of the study, a total of 0.114% of dicamba volatilized and was lost from the field. The reviewer estimated a peak flux rate of 0.000965 $\mu g/m^2 \cdot s$, accounting for 0.059% of the applied dicamba observed 1.2 to 10.7 hours post-application, and a total of 0.141% of dicamba volatilized and was lost from the field by the end of the study. Peak volatile flux occurred during warm daytime hours.

Spray drift measurements indicated that dicamba residues were detected at very low levels (maximum fraction of 0.000002 of the applied) in upwind samples at one hour after application and were detected at a maximum fraction of the amount applied of 0.009495 in downwind samples and 0.003664 in left wind samples. Deposition of dicamba above the no observed adverse effects concentration (NOAEC) was detected in all transects of the downwind and left wind directions in the one-hour sampling period. Study authors estimated distances from the edge of the field to reach NOAEC for soybean ranged from 9.8 to 18.2 m in the downwind direction and 14.6 to 15.3 m in the left wind direction. Reviewer-estimated distances were 14.2 m (11.4 to 16.1 m for the three transects) and 11.5 m (7.7 to 14.1 m for the two transects) in the downwind and left wind directions, respectively.

Figure 1 Volatile flux – Soybean Plot



Plant effects (51049003, EPA Guideline 850.4150; Supporting files in Appendix 2)

The effect of **BAS 183 22H (a.i. Dicamba BAPMA salt) + MON 79789 (a.i. Glyphosate potassium salt) + Adjuvant Intact™** on the vegetative vigor of dicot (soybean, *Glycine max)* crops was studied in a spray drift and volatilization study. Nominal test concentrations of Dicamba were 0.50 lb ae/A and Glyphosate were 1.125 lb ae/A. Dicamba test concentrations were analytically confirmed by monitoring field filter collectors during spray application as well as measurement of pre-application and post-application tank solutions; nominal and measured application rates are provided in Table 4. On days 15 and 27 after treatment, the surviving plants along several transects projecting from the treated area were measured for height and visual signs of injury (VSI).

There are several concerns with the conduct and conditions of this study. In terms of the utility of the volatility transects (covered transects), a storm event occurred on Day 2, between hours 23 and 29, reducing the emissions from volatility. This reduction impacts the amount of material that the transects may have been exposed to via volatility. Distances based on vapor exposure alone (covered transects) will reflect plant responses to this lowered exposure and may underestimate distances under conditions of no rainfall.

A significant dicamba exposure event occurred prior to the application of dicamba to the field, as evidenced from VSI (5-10%) across all study transects, including controls, 1 day prior to application. The effects in controls may have continued to increase or a second exposure event following application added to the previous injury, by 15DAT VSI in the controls was 10% and persisted through 27DAT. This exposure event, having been observed over the entire non-dicamba tolerant crop, contributes to VSI that was observed in the transects used for defining distances above. The extent to which this may increase the distance estimates for 10% VSI cannot be discerned with the available information. The lack of a trend of VSI across the field on 1-day prior to application suggests an exposure route different from spray drift deposition.

Spray Drift + Volatility Study

Dicamba-non-tolerant soybean were planted in test plots at distances of approximately 3, 5, 10, 20, 40, 50, 60 and 90 meters from the edge of the treatment application field in the downwind, upwind, and lateral directions.

When compared to the negative control plot, there were significant inhibitions in seedling height in along most transects. DW, LW and NE transects showed distance-dependent response of lower plant heights near the application area than further away. In the DWA, DWB, DWC, LWA, LWB, UWA, UWB, NE, SE and SW the distance to 10%VSI extending out to or beyond 60m (maximum 112 m).

Furthest distance to 5% Reduction in Plant Height 63.7 meters (209 feet)
Furthest distance to 10% VSI = 112 meters (366 feet)

Volatility Study

At 28 DAT, VSI 5 to 45% were reported in all volatility transects. A strong signal of distance to effect was observed for several volatility transects, with LWA, LWB, and RWB having 25-35% VSI at the furthest sampling distance (**Table 1**).

Significant reductions in plant heights were also observed to have strong distance to effect patterns (i.e., more reduction closer to the treated area) in areas downwind of the treated area (e.g., DW and LW transects, **Table E.10**). Although the study author attempted to minimize variability by selecting plot distances that had plants of similar height at the start of the study, plant height differed across the field due to responses of the condition of the field. Therefore, due to the non-uniformity of plant height across the field, there increased uncertainty in the distance estimates based on a 5% reduction relative to the control growth. The impact of dicamba specific reductions in plant height are confounded by field conditions and differential growth rates across the non-tolerant soybean crop such that reduction of expected plant height (i.e., 5% reduction of mean control height) as a result of dicamba exposure is likely masked by the variable nature of conditions in the field.

Furthest distance to 5% Reduction in Plant Height > 20 meters (>66 feet)
Furthest distance to 20% VSI = 33.4 meters (109.6 feet)

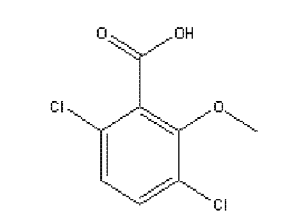
Table 1. Estimated distances to regulatory threshold responses for reductions in plant height and visible signs of injury.

Exposure Pathway	Spray Drift + Volatility (uncovered transects)		Volatility (covered transects)	
Transect	Distance to 5% Height (meters)	Distance to 10% VSI (meters)	Distance to 5% Height (meters)	Distance to 10% VSI (meters)
DWA	63.7[b]	91.0[b]	>3[d]	14.2[c]
DWB	42.5[b]	103.0[c]	>3[d]	12.6[c]
DWC	24.4[b]	60.5[b]	>20[d]	3.4[a]
LWA	>60[d]	87.3[a]	<3[d]	33.4[c]
LWB	21.3[a]	111.6[c]	<3[d]	30.1[c]
UWA	>60[d]	>60[d]	>20[d]	9.5[c]
UWB	>40[d]	>60[d]	>20[d]	3[d]
RWA	>5[d]	13.8[a]	>3[d]	<20[d]
RWB	>60[d]	2.2[a]	>20[d]	>20[d]
NE	25.7[a]	60.6[b]	NA	NA
NW	<10[d]	<3[d]	NA	NA
SE	>60[d]	>60[d]	NA	NA

[a] distance estimated with logistic regression
[b] distance estimated with polynomial regression
[c] distance estimated with linear regression
[d] distance estimated visually
NA = Not applicable

I. Materials and Methods

A. Materials



1. Test Material

Product Name: BAS 183 22 H (dicamba in the form of its N,N-Bis-(3-aminopropyl)methylamine (BAPMA) salt; Appendix B, pp. 101-102)
Formulation Type: SL
CAS #: 105-83-9
Lot Number: 7195N01DD
Storage stability: The expiration date of the test substance was July 18, 2020.

Product Name: Roundup PowerMax® (Glyphosate, (N-(phosphonomethyl) glycine potassium salt; Appendix B, p. 103)
Formulation type: Not reported
CAS Number: Not reported

Lot Number: 11495283
Storage stability: The expiration date of the test substance was May 7, 2020.

Product Name: Intact (polyethylene glycol, choline chloride, guar gum)
Formulation type: Not reported
Lot Number: 0831B037000 (Batch# 374-25)
Storage stability: The expiration date of the test substance was September 11, 2022.

Product Name: Approved buffering agent (ABA)
Formulation type: Not reported
Lot Number: LH-171009-0001
Storage stability: The expiration date of the test substance was June 22, 2022.

2. Storage Conditions

The test substance was received on June 20, 2019 and stored at Stoneville R&D, Inc., Greenville, Mississippi (Appendix B, p. 102). Roundup PowerMax® and Intact™ were received on May 9, 2019. The ABA was received on April 18, 2019. The test substance was sprayed on the test plot on June 22, 2019 (Appendix B, p. 106). The study protocol indicates the test substance would be stored under label conditions in a monitored pesticide storage area adequate to preserve stability (Appendix A, p. 35).

B. Study Design

1. Site Description

The test site was located in Washington County, Mississippi, *ca.* 7.5 miles east of the Mississippi River and 11.3 miles northeast of Stoneville R&D (Appendix B, p. 104). A single soybean-cropped field, measuring *ca.* 302 m × 302 m (*ca.* 22.5 A) was treated with a mixture of BAS 183 22 H (containing dicamba in the form of its N,N-Bis-(3-aminopropyl)methylamine (BAPMA) salt), Roundup PowerMax® (containing glyphosate potassium salt), Intact™ (polyethylene glycol, choline chloride, and guar gum), and an approved buffering agent (Appendix B, p. 102). The crop on the plot was a dicamba-tolerant soybean crop (Variety: AG45X8, Lot: HU8SEC1B) with an approximately 430-ft no-spray buffer surrounding the plot planted in non-tolerant soybeans (Variety: NKS45-W9, Lot: 14287759). Soil characterization indicated the USDA textural class was clay (Appendix B, Table 2, p. 122). The study indicated that the most recent application of dicamba did not occur within the last three years (Appendix B, p. 105), although application records indicate an application of Engenia Herbicide on 6/4/2018 (Appendix B, p. 177). Crop history for the three years preceding the study indicated the field had been planted in soybeans (Appendix B, pp. 165-178). Terrain was flat with a slope between 0 and 1%. The test plot was surrounded by agricultural land (Appendix B, Figure 1, p. 140). The test plot and surrounding buffer zone were planted with soybean on April 29, 2019 and replanted on May 24, 2019 as a result of low emergence due to heavy rain (Appendix B, p. 104). The soybean seeds were planted at a density of 134,000 seeds/A on 30-inch row spacing for both plantings.

2. Application Details

Application rate(s):	The target application rate was 0.5 lb a.e./A or 15 GPA (Appendix A, p. 35; Appendix B, p. 106). Four application monitoring samples consisting of four filter paper samples each were positioned in the spray area in locations to capture various portions of the spray boom (Appendix B, p. 109). The spray rate was automatically maintained by a variable rate controller (Appendix B, p. 115). Based on Climate FieldView™ software, the actual application rate was 103% of the target application rate or 15.5 GPA (Appendix B, Table 1, p. 121).
Irrigation and Water Seal(s):	No irrigation or water seals were reported in the study. Precipitation of 2.02 and 2.57 inches occurred on 6/23 and 6/24/19, at 1 and 2 days posttreatment, respectively (Appendix B, Table 12, p. 134). Rain started around 7:30 pm on 6/23 and ended around 4:30 am on 6/24 (meteorological file).
Tarp Applications:	Tarps were not used on the test plot. Tarps were used on nine plant effects transects before application, during application, and for at least 30 minutes following application to prevent exposure to spray drift to assess secondary movement only (Appendix A, p. 41).
Application Equipment:	A Case SPX 3230 Patriot ground sprayer equipped with a 90-ft boom was used for the spray application (Appendix B, p. 105). 54 Fifty-four Turbo TeeJet® Induction nozzles (TTI 11004) were installed with 20-inch spacing and the boom height was set at 20 inches above the crop canopy (20 cm). The sprayer had one spray tank with a volume of 800 gallons.
Equipment Calibration Procedures:	Nozzle uniformity was tested by spraying water at a pressure of 63 psi through the boom and measuring nozzle output using SpotOn® Model SC-1 sprayer calibrator devices (Appendix B, p. 105). Each nozzle was tested three times to determine variability. Calibration of the sprayer and nozzles established the total boom output per minute of spray to be 26.1 GPM. The forward speed of the sprayer tractor was calibrated by timing the duration required, in seconds, to drive a known distance of 1320 ft. Speed verification was repeated six times.
Application Regime:	The application rates and methods used in the study are summarized in **Table 2**.

Table 2. Summary of application methods and rates for dicamba

Field	Application Method	Time of Application (Date and Start Time)	Amount Dicamba Applied[1] (lbs)	Area Treated (acres)	Calculated Application Rate[2] (lb ae/acre)	Reported Application Rate (gal/acre)
Soybean	Spray	6/22/2019 at 9:06	11.6	22.5	0.515	15.5

Data obtained from Appendix B, pp. 105-106 and Appendix B, Table 1, p. 121 of the study report.
[1] Reviewer calculated as calculated application rate (lb a.e./acre) × area treated (acres).
[2] Reviewer calculated as percent of target applied (103%) × target application rate (0.5 lb a.e./acre, Appendix B, Table 1, p. 121).

Application Scheduling: Critical events of the study in relation to the application period are provided in **Table 3**.

Table 3. Summary of dicamba application and monitoring schedule

Field	Treated Acres	Application Period	Initial Air/Flux Monitoring Period[1]	Water Sealing Period	Tarp Covering Period
Soybean	*ca.* 22.5	6/22/2019 between 9:06 – 9:30	6/22/2019 between 9:41 – 20:25	Not Applicable	Not Applicable

Data obtained from Appendix B, p. 106; and Appendix B, Table 5, p. 125 of the study report.
[1] Initial air monitoring period is that for perimeter stations. The initial period at the center station was 6/22/2019 between 10:20 – 19:47.

3. Soil Properties

Soil properties measured before the study are provided in **Table 4**. pH of the soil was 7.1 (Appendix B, p. 108; Table 2, p. 122).

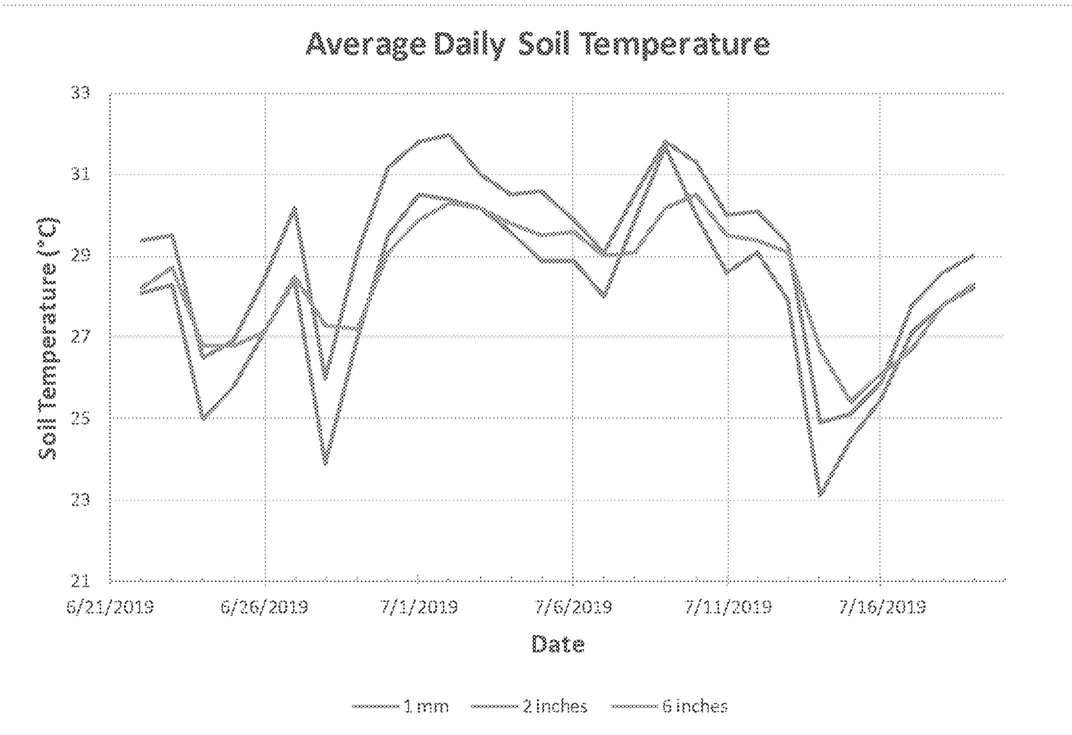
Table 4. Summary of soil properties for the soybean plot

Field	Sampling Depth (inches)	USDA Soil Textural Classification	USGS Soil Series	WRB Soil Taxonomic Classification	Bulk Density (g/cm^3)	Soil Composition
Soybean	0-6	Clay	Not Reported	Not Reported	1.07	% Organic Carbon[1] = 1.22% % Sand = 31% % Silt = 18% % Clay = 51%

Data obtained from Appendix B, pp. 108, 116, and Appendix B, Table 2, p. 122 of the study report.
[1]Reviewer calculated as: organic carbon (%) = organic matter (%)/1.72.

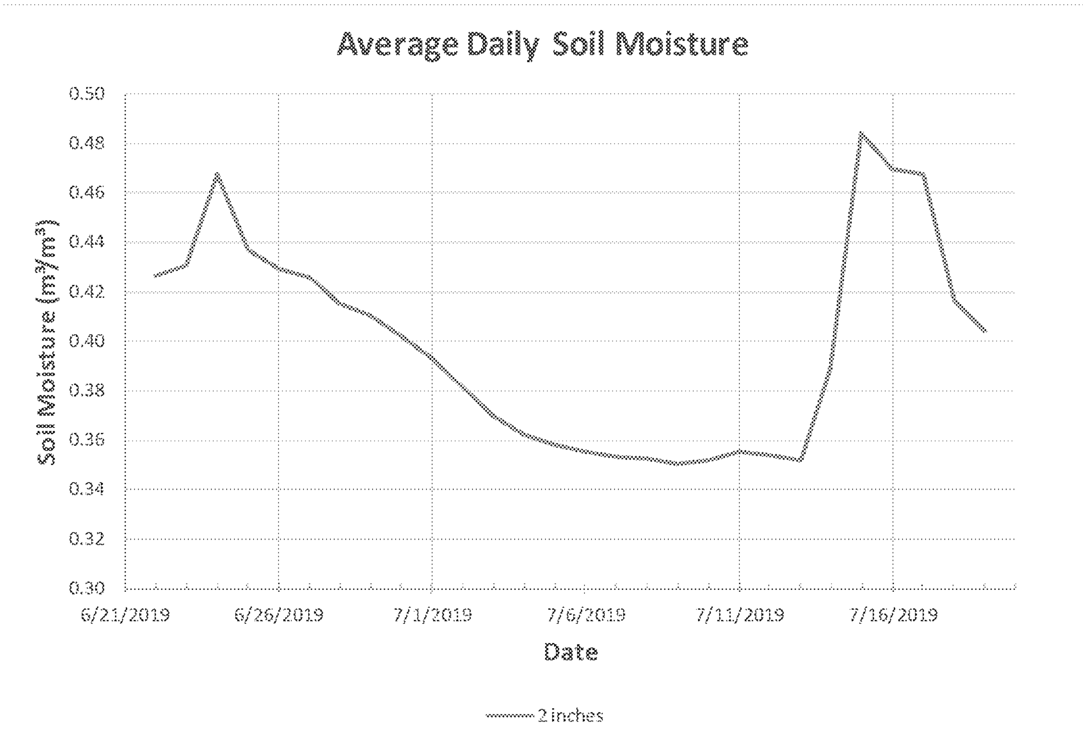
Figures 2 and **3** are plots of soil temperature and soil moisture measured throughout the study.

Figure 2 Soil temperature measured throughout the study



Data obtained from Appendix B, Table 13, pp. 136-137 of the study report.

Figure 3 Soil moisture measured throughout the study



Data obtained from Appendix B, Table 13, pp. 136-137 of the study report.

4. Source Water

Tank mix water was obtained from a well located at GT&T Farms. The pH of the tank mix water was 8.8 as measured at the analytical laboratory of 8.1, an alkalinity of 312 mg $CaCO_3$/L, and a conductivity of 0.61 mmhos/cm.

5. Meteorological Sampling

Five meteorological stations were used to collect weather data during the study (Appendix B, p. 106).

The 10-meter main meteorological station was located upwind of the test plot (Appendix B, pp. 106-107, and Figure 3, p. 142). The system included a Campbell CR6 data logger and a Campbell Scientific CELL210 module to remotely monitor data. The station included sensors for monitoring windspeed and direction, air temperature, and relative humidity. All parameters were reported at heights of 1.7, 5, and 10 m above the ground.

A boom height anemometer collected wind speed and wind direction data during application at a height of 51 cm above the crop canopy (Appendix B, p. 107). The anemometer was located *ca.* 3 m downwind of the sprayed area.
The long duration main meteorological station was located upwind of the test plot and recorded data for 27 days post-test substance application (Appendix B, p. 107, and Table 13, pp. 136-137). The station included wind speed and direction sensors (1.7 m), rain gauge sensor (1.5 m), a temperature/relative humidity sensor (1.25 m), a pyranometer to measure solar irradiation (1.5 m), three soil temperature sensors (depths of 1 mm, 2 inches, and 6 inches), and one soil moisture sensor (depth of 2 inches).

The primary flux meteorological station was deployed outside of the plot prior to and during application and was then moved to the center of the plot, remaining there until after the final sample was collected on June 29, 2019 (Appendix B, p. 107). The station included a Campbell CR6 data logger and a Campbell Scientific CELL210 module to remotely monitor data. The station included sensors for air temperature, relative humidity, wind speed, and wind direction at heights of 0.33, 0.55, 0.9, and 1.5 m above the crop canopy.

A secondary flux meteorological station also recorded air temperature, relative humidity, wind speed, and wind direction at heights of 0.33, 0.55, 0.9, and 1.5 m above the crop canopy (Appendix B, p. 107). The secondary meteorological station was a backup flux meteorological station and was positioned upwind and outside of the sprayed area.

Details of the sensor heights and the meteorological parameters for which data were collected are illustrated in **Table 5**. The location of the meteorological equipment is shown in **Attachment 3**.

Table 5. Summary of meteorological parameters measured in the field

Field	Minimum Fetch (m)	Parameter	Monitoring heights[1] (m)	Averaging Period
Soybean Plot 10-Meter Main	Not Reported	Air temperature	1.7, 5, and 10	1 minute
		Relative humidity	1.7, 5, and 10	1 minute

Field	Minimum Fetch (m)	Parameter	Monitoring heights[1] (m)	Averaging Period
Met. Station		Wind speed/wind direction	1.7, 5, and 10	1 minute
Soybean Plot Boom Height Anemometer	Not Reported	Wind speed/wind direction	0.51	Not Reported
Soybean Plot Long Duration Main Met. Station	Not Reported	Precipitation	1.5	1 minute
		Air temperature	1.25	1 minute
		Relative humidity	1.25	1 minute
		Soil temperature	1 mm, 2 inches, 6 inches	1 minute
		Soil moisture	2 inches depth	1 minute
		Solar radiation	1.5	1 minute
		Wind speed/wind direction	1.7	1 minute
Soybean Plot Primary Flux Met. Station	165.19	Air temperature	0.33, 0.55, 0.9, and 1.5	1 minute
		Relative humidity	0.33, 0.55, 0.9, and 1.5	1 minute
		Wind speed/wind direction	0.33, 0.55, 0.9, and 1.5	1 minute
Soybean Plot Secondary Flux Met. Station	Not Reported	Air temperature	0.33, 0.55, 0.9, and 1.5	1 minute
		Relative humidity	0.33, 0.55, 0.9, and 1.5	1 minute
		Wind speed/wind direction	0.33, 0.55, 0.9, and 1.5	1 minute

Data obtained from Appendix A, pp. 43-44, 76; Appendix B, pp. 106-107; and Appendix D, Table 8, p. 561 of the study report.

[1] Monitoring heights are above soil surface for the 10-meter main meteorological station and long duration main meteorological station. Heights are above crop canopy for the boom height anemometer and flux meteorological stations.

6. Air Sampling

Two pre-application samples were collected at 0.15 m above the crop surface at the approximate center of the test plot (Appendix B, p. 110). Samples were collected for *ca.* 6 hours on June 21, 2019 from 11:01 to 17:18.

Post-application in-field air samplers were used for flux monitoring for *ca.* 168 hours following application (Appendix B, pp. 110-111). Samplers were placed on a mast in the approximate center of the plot directly following spray application at heights of 0.15, 0.33, 0.55, 0.90, and 1.5 m above the crop surface (20 cm). Samples were collected at *ca.* 6, 24, 36, 72, 84, 96, 108, 120, 132, 144, 156, and 168 hours post-application. Sample collection for the 0 to 6-hour interval was pro-rated based on the time remaining until sunset on the day of application. These samples represented more than 6 hours of sampling. Following the 6 to 12-hour interval, sampling was completed on a sunrise-sunset schedule, with consistent morning and evening sampling times.

Off the plot, eight perimeter air monitoring stations were located 1.5 m above the crop canopy and 5 m outside the edge of the plot (Appendix B, pp. 110-111). Samples were collected at *ca.* 6, 24, 36, 72, 84, 96, 108, 120, 132, 144, 156, and 168 hours post-application. The sampling schedule was the same as for the in-field air sampling.

Samples were not collected for the 6 to 12-hour interval due to the logistics of performing two studies in one day. Due to flooding following a severe thunderstorm on the evening of 6/23/19 that made access to the field unsafe, the 24 to 36-hour samples were deployed for over 30 hours (over 35 hours for the perimeter samplers) and the 36 to 48-hour and 48 to 60-hour samples were not deployed or collected.

7. Spray Drift Monitoring

The spray drift test system consisted of three downwind transects, two left wind transects, two right wind transects, and two upwind transects (Appendix B, pp. 111-112). All transects were perpendicular to the edge of the field. Deposition collectors (Whatman #1 15 cm diameter filter papers) were placed on all transects at the following distances from the edge of the spray area: 3, 5, 10, 20, 40, 50, and 60 m. Deposition collectors were also placed at 90 m in the downwind transects only. Deposition collectors were secured to carboard squares and attached to a horizontal plastic platform at crop height. Initial deposition samples were collected 5 minutes after spray application was completed. Deposition samples were then collected at intervals of 1, 24, 48, 72, 96, 120, 144, and 168 hours post-application (Appendix B, pp. 127-128). Spray drift samples representing 24-48 hours post-application were destroyed by a thunderstorm and not collected (p. 14). Spray drift samples from 72 hours post-application were not collected for the upwind, downwind, and left wind transects. Several deposition samples were also not collected during the 168 hour post-application interval due to precipitation on 6/28/19.

8. Plant Effects Monitoring

The off-target movement of dicamba due to spray drift and volatility following the application of dicamba to dicamba-tolerant soybeans was assessed by comparing plant heights and visual plant symptomology along transects of non-tolerant soybean crop surrounding the tolerant soybean field and perpendicular to the sprayed field edges of the application area, as well as four transects radiating from the corners of the sprayed field out to a maximum distance of approximately 90 meters (Appendix G, pp. 708-709; Figure 2, p. 737). Height effects and visual symptomology was recorded at 0, 14, and 28 days after spray application of the tank mix. Dicamba-non-tolerant soybean were evaluated at distances of approximately 3, 5, 10, 20, 40, 50, 60 and 90 meters (downwind only) from the edge of the treatment application field. Transects were not located within pre-determined designated ingress and egress areas for the sprayer. Along with the plant effect transects located immediately adjacent to the treated field, four upwind control areas were identified and evaluated for plant height.

Plant effects from volatility were assessed by isolating a portion of the non-tolerant soybean crop immediately adjacent to the treated areas using plastic sheeting (transect covers) during the application period to prevent exposure to spray drift (Appendix G, pp. 708-709; Figure 3, p. 738). The non-tolerant soybeans that were covered during the application were used to assess effects to plant height and visual symptomology from dicamba volatility. The plastic covers were intended to remain in place for approximately 30 min post-application before permanent removal for the remainder of the study. Transects for volatility only were 20 m long and plant height measurements and visual symptomology ratings were completed at approximately 3, 5, 10, and 20 m from the sprayed area at 0, 14, and 28 days after treatment.

At each distance along each transect, ten plants were selected non-systematically with no attempt to measure the same plant at the subsequent time points. Plant height was measured by holding a plant upright and measuring the distance between the ground and the tip of the most recently emerged apical bud to the nearest centimeter using a metal metric ruler. Where multiple shoots were present, measurements along the main shoot were taken.

9. Sample Handling and Storage Stability

PUF sorbent tube and deposition filter paper samples were handled with nitrile gloves, which were replaced after the collection of samples and prior to installation of a new sample media for the next sampling interval (Appendix B, p. 108). PUF sorbent tubes and filter papers were placed in pre-labeled conical tubes. Pre-application PUF samples and post-application PUF samples were stored in separate freezers at *ca.* -20°C freezer prior to shipment. Downwind, left wind, right wind, and upwind filter paper samples and application monitoring samples were stored in separate coolers packed with dry ice and shipped to the analytical lab. Field-exposed spikes and transit stability samples were stored in coolers containing dry ice. All samples were shipped in coolers on dry ice to the analytical test site, Eurofins, in Columbia, Missouri.

All field collected PUF and filter paper samples were extracted within 18 and 14 days, respectively, after collection (Appendix C, p. 264-265). All field exposed QC and transit stability samples were extracted within 18 days after fortification. All PUF and filter paper samples were analyzed within 2 and 3 days of extraction, respectively. All PUF and filter paper samples were analyzed within 20 and 15 days of sampling, respectively (Appendix C, pp. 427-446). Stability was demonstrated in the study by the recovery of dicamba in fortified field QC and transit stability samples run concurrently with the field samples.

10. Analytical Methodology

- Sampling Procedure and Trapping Material: Flux monitoring equipment consisted of PUF collectors and tubing protected from precipitation by ¾ inch diameter PVC pipe (Appendix B, p. 109). SKC air sampling pumps were used, covered with plastic bags to protect them from precipitation. Pumps were calibrated to a flow rate of 3.000 ± 0.050 L/min.

- Extraction method: The contents of the PUF sorbent tubes were extracted using methanol containing stable-labeled internal standard (Appendix C, pp. 264, 319-346). The sample was fortified with internal standard, grinding balls were added to the tube, and 29.8 mL of methanol was added. The sample tubes were capped and agitated on a high-speed shaker (Geno/Grinder®) for 1200 cycles per minute for 30 minutes. The cap was removed, and a 1.5 mL aliquot was transferred to a 0.45 µm polypropylene 96-well filter plate with a clean glass-lined polypropylene plate (2 mL) positioned below the filter plate (Appendix C, pp. 328-329). The sample was evaporated to dryness under nitrogen at 50°C. The sample was reconstituted with 25% methanol in water. The sample was mixed and analyzed by LC-MS/MS with electrospray ionization in negative ion mode.

  The filter paper samples were extracted using methanol containing stable-labeled internal standard. The sample was fortified with internal standard, grinding balls were added to the tube, and 29.9 mL of methanol was added. The sample tubes were capped and agitated on a high-speed shaker (Geno/Grinder®) for 1200 cycles per minute for 5 minutes. The tubes were then placed in a ≤10°C centrifuge (4500 xg for 5 minutes) and spun to clear suspended materials from the liquid column and form a solid pellet. The cap was removed and a 0.35 mL aliquot was transferred to a clean 96-well filter plate with a clean, glass-lined polypropylene plate positioned below the filter plate. The plates were then placed in a ≤10°C centrifuge (1500 xg for 1 minute) and spun until liquid passed through the plate. The solution was analyzed by LC-MS/MS with electrospray ionization in negative ion mode (Appendix C, p. 347-366).

- Method validation (Including LOD and LOQ): Method validation was achieved by fortifying 18 replicate fortification samples at each of three fortification levels (0.3 ng/PUF, 3 ng/PUF, and 60 ng/PUF; Appendix C, pp. 337-341). Validation assessments showed acceptable accuracy between 70% and 120% and precision (<20% RSD) for all fortified matrices at each fortification level for both primary and secondary ion transitions. Average recoveries for primary ion transitions were 89%, 94%, and 90% at 0.3, 3, and 60 ng/PUF, respectively. Average recoveries for secondary ion transitions were 93%, 97%, and 98% at 0.3, 3, and 60 ng/PUF, respectively. No independent laboratory validation is provided. For primary ion transitions, the LOQ during method validation was 0.30 ng/PUF and the LOD was 0.094 ng/PUF (Appendix C, p. 338). For secondary ion transitions, the LOQ during method validation was 0.30 ng/PUF and the LOD was 0.065 ng/PUF. During the study, the LOQ was 1.0 ng/PUF (p. 15).

  Method validation was achieved by fortifying 6 replicate fortification samples at each of three fortification levels (0.005, 0.10, and 4.8 μg/filter paper; Appendix C, pp. 361). Validation assessments showed acceptable accuracy between 70% and 120% and precision (<20% RSD) for all fortified matrices at each fortification level. Average recoveries were 81%, 117%, and 104% at 0.005, 0.10, and 4.8 μg/filter paper, respectively. No independent laboratory validation is provided, although results from Field Deposition Study REG-2015-004 confirmed the results. The LOQ during method validation was 0.005 μg/filter paper (Appendix C, p. 347). During the study, the LOQ was 0.005 μg/filter paper (p. 15).

- Instrument performance: Calibration standards were prepared at concentrations ranging from 0.15 to 75 ng/PUF (Appendix C, p. 325). Concentrations were 0.15, 0.225, 0.3, 0.75, 1.5, 2.25, 3, 7.5, 15, 22.5, 30, and 75 ng/PUF. Analyst® software was used to derive the calibration curve using a weighted linear curve (1/x; Appendix C, pp. 331 and 384).

  Calibration standards were prepared at concentrations ranging from 0.0015 to 6 μg/filter paper (Appendix C, p. 352). Concentrations were 0.0015, 0.003, 0.0075, 0.015, 0.03, 0.075, 0.15, 0.3, 0.75, 1.5, 3, and 6 μg/filter paper. Analyst® software was used to derive the calibration curve using a weighted quadratic curve (1/x; Appendix C, pp. 357 and 400).

11. Quality Control for Air Sampling

Lab Recovery: 18 of 24 laboratory spike recoveries are within the acceptable range of 90-110% (Appendix C, pp. 387-388). All laboratory spike recoveries are within the range of 82-122%. Laboratory spike samples were prepared at fortification levels of 1 ng/PUF (12 samples) and 60 ng/PUF (12 samples). Average recoveries were 101% and 103% at 1 ng/PUF and 60 ng/PUF, respectively (Appendix C, Table 5, p. 274; pp. 387-388).

Field blanks: Two pre-application samples were collected from the center of the test plot from 11:01 to 17:18 on June 21, 2019, one day before application (Appendix B, p. 110). Dicamba was not detected in pre-application samples (Appendix B, p. 117).

Control samples from the field spike analysis did not contain detectable levels of dicamba in the six samples (Appendix C, Table 8, p. 281).

Field Recovery: Nine 6-hour and nine 12-hour field spike samples were collected at concentration levels of 3, 10, and 30 ng/PUF. A total of six field spikes were prepared at each concentration level. Field spike recoveries had overall recoveries of 86% to 103% at 3 ng/PUF, 72% to 97% at 10 ng/PUF, and 85% to 103% at 30 ng/PUF (Appendix B, p. 117; Appendix C, Table 8, p. 281).

Travel Recovery: Three transit stability PUF samples were fortified at 30 ng/PUF and placed on dry ice along with three unfortified control samples (Appendix B, p. 114). Dicamba was detected in one of three control samples at 1.90 ng/PUF; the range of recoveries from the fortified samples was from 84% to 104% (Appendix C, Table 9, p. 282).

Breakthrough: Laboratory spike samples that were fortified at 60 ng/PUF had recoveries ranging from 88% to 116% (Appendix C, pp. 387-388). The highest dicamba amount measured on a PUF sample (excluding laboratory and field spikes) was 20.2 ng/PUF (Appendix C, pp. 391-397) which is *ca.* 34% of the highest fortification level, indicating that dicamba loss due to breakthrough is unlikely.

12. Quality Control for Deposition Sampling

Lab Recovery: 44 of 45 laboratory spike recoveries were within the acceptable range of 90-110%. All laboratory spike recoveries are within the range of 98-113%. Laboratory spike samples were prepared at fortification levels of 0.005 µg/filter (21 samples), 5 µg/filter (21 samples), and 50 µg/filter (3 samples). Average recoveries were 105%, 104%, and 103% at 0.005 µg/filter, 5 µg/filter, and 50 µg/filter, respectively. Control samples from the field spike analysis did not contain detectable levels of dicamba (Appendix C, p. 403-405).

Travel Recovery: Five transit stability filter paper samples were fortified at 0.05 µg/filter paper and placed on dry ice along with five unfortified control samples (Appendix C, p. 297). Dicamba was not detected in the control samples. The range of recoveries from the fortified samples was from 96% to 100%.

13. Application Verification

Four application monitoring sampling stations, each consisting of four 12.5 cm diameter Whatman #3 filter paper samples, were positioned in the spray area at the crop height of 20 cm (Appendix B, p. 109). The stations were positioned to capture different portions of the spray boom and different spray nozzles. The average recovery relative to the target was 96% (Appendix B, p. 117; Appendix B, Table 14, p. 138; and Appendix C, Table 2, p. 271).

Spray application rates were automatically maintained by the sprayer using a variable rate controller (Appendix B, p. 115). The application rate was assumed to be 100% of the target rate, and pass times were not used to calculate an application rate. Based on Climate FieldView™ software application data, the actual application rate was 103% of the target rate (Appendix B, Table 1, p. 121).

Tank mix samples were also collected and analyzed to verify the amount of dicamba present in the tank mix (Appendix B, p. 109). Mean recovery was 97% and 98% of nominal, respectively, before and after application (Appendix C, Table 4, p. 273).

14. Deposition and Air Concentration Modeling

Off-target air concentrations and deposition were calculated based on the calculated flux rates and relevant meteorological data. U.S. EPA's AERMOD model (version 18081) was used to estimate deposition, while the Probabilistic Exposure and Risk model for Fumigants (PERFUM2, version 2.5) was used to estimate air concentrations (Appendix E, p. 590). Three sets of estimates were calculated, using meteorological data for Raleigh, North Carolina; Peoria, Illinois; and Lubbock, Texas (Appendix E, p. 590). The reviewer used PERFUM version 3.2 to estimate air concentrations using the same meteorological data.

The maximum flux predicted by any method for each period was chosen to represent that period. Periods were then mapped onto hours of the day (1- 24), where the maximum flux rate for each hour was then chosen to represent that hour, regardless of the day from which it was collected. In cases where two periods occurred in a single hour, a weighted average of the flux rates was used. The 24-hour flux profile for the first two days were used as inputs for PERFUM and the average flux rate and as adjustment factors for input into AERMOD. The reviewer and study author flux rates were slightly different. However, they did not impact the overall modeling conclusions.

Wet and dry deposition estimates were made at 10 distances from the field (5, 10, 20, 30, 40, 50, 75, 100, 125, and 150 m; Appendix E, p. 592). For the fluxes from the soybean plot at a distance of 5 m from the edge of the field, maximum 24-hour average total (dry+wet) deposition ranged from 5.98 to 6.60 $\mu g/m^2$ (Appendix E, Table 7, pp. 605-606). 90^{th} percentile 24-hour average total deposition ranged from 3.03 to 3.95 $\mu g/m^2$.

Modeled dicamba air concentrations were calculated at 4 distances from the field (5, 10, 25, and 50 m; Appendix E, pp. 591-593). Modeled 95^{th} percentile 24-hour air concentrations ranged from 10.8 to 17.2 ng/m^3 at 5 m from the edge of the treated field and 7.8 to 12.6 ng/m^3 at 50 m from the edge of the field (Appendix E, Table 6, p. 604).

The reviewer was able to confirm the modeling conclusions both for deposition and air concentrations. The reviewer also conducted modeling analysis for Little Rock, Arkansas, Nashville, Tennessee, and Springfield, Missouri, attempting to capture modeling results representative of soybean growing regions in Arkansas, Tennessee, and Missouri. Modeled 95th percentile 24-hour air concentrations were slightly higher (19-42 ng/m3), but comparable, than those achieved for the North Carolina, Illinois, and Texas modeling results.

II. Results and Discussion

A. Empirical Flux Determination Method Description and Applicability

Indirect Method

The indirect method, commonly referred to as the "back calculation" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the indirect method, air samples are collected at various locations outside the boundaries of a treated field. Meteorological conditions, including air temperature, wind speed, and wind direction, are also collected for the duration of the sampling event. The dimensions and orientation of the treated field, the location of the samplers, and the meteorological information are used in combination with the AERMOD dispersion model (Version 18081) and a unit flux rate of 0.001 g/m2·s to estimate concentrations at the sampler locations. Since there is a linear relationship between flux and the concentration at a given location, the results from the AERMOD model runs are compared to those concentrations actually measured, and a regression is performed, using the modeled values along the x-axis and the measured values along the y-axis. If the linear regression does not result in a statistically significant relationship, the regression may be rerun forcing the intercept through the origin, or the ratio of averages between the monitored to modeled concentrations may be computed, removing the spatial relationship of the concentrations. The indirect method flux back calculation procedure is described in detail in Johnson et al., 1999.

Study authors used a similar analysis to obtain flux rates. However, if, after regression analysis, the linear regression did not result in a statistically significant relationship, instead of rerunning the regression by forcing the intercept through zero, the spatial relationship was removed by sorting both the measured and modeled air concentrations (independently) in ascending order, then redoing the regression, with the final flux estimate calculated as the slope of this alternative regression multiplied by the nominal flux. If the sorted regression was also not statistically significant, the ratio of the sum of the measured concentrations to the sum of the modeled concentrations was multiplied by the nominal flux to get the final flux estimate.

Aerodynamic Method

The aerodynamic method, also referred to as the "flux-gradient" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data.

In the aerodynamic method, a mast is erected in the middle of the treated field and concentration samples are typically collected at four or five different heights, ranging from 0.5 to 10 feet. Likewise, temperature and wind speed data are collected at a variety of heights. A log-linear regression is performed relating the natural logarithm of the sample height to the concentration, temperature, and wind speed. These relationships are then incorporated into an equation to estimate flux. The methods to estimate flux and related equations are presented in Majewski et al., 1990. The equation for estimating flux using the aerodynamic method is Thornthwaite-Holzman Equation, which is shown in the following expression:

Equation 1 $$P = \frac{k^2(\Delta\bar{c})(\Delta\bar{u})}{\phi_m \phi_p [\ln\left(\frac{z_2}{z_1}\right)]^2}$$

where P is the flux in units of $\mu g/m^2 \cdot s$, k is the von Karman's constant (dimensionless ~0.4), $\Delta\bar{c}$ is the vertical gradient pesticide residue concentration in air in units of $\mu g/m^3$ between heights z_{top} and z_{bottom} in units of meters, $\Delta\bar{u}$ is the vertical gradient wind speed in units of m/s between heights z_{top} and z_{bottom}, and ϕ_m and ϕ_p are the momentum and vapor stability correction terms respectively. Following the conditions expected in the neutrally stable internal boundary layer characterized by an absence of convective (buoyant) mixing but mechanical mixing due to wind shear and frictional drag, a log-linear regression is performed relating the natural logarithm of the sample height to the concentration, temperature, and wind speed. The adjusted values of the concentration, temperature, and wind speed from this regression is incorporated into Equation 1 to arrive at Equation 2 which is ultimately used to compute the flux.

Equation 2 $$Flux = \frac{-(0.42)^2(c_{ztop} - c_{zbottom})(u_{ztop} - u_{zbottom})}{\phi_m \phi_p \ln\left(\frac{z_{top}}{z_{bottom}}\right)^2}$$

where ϕ_m and ϕ_p are internal boundary layer (IBL)stability correction terms determined according to the following conditions based on the calculation of the Richardson number, R_i:

Equation 3 $$R_i = \frac{(9.8)(z_{top} - z_{bottom})(T_{ztop} - T_{zbottom})}{\left[\left(\frac{T_{ztop} + T_{zbottom}}{2}\right) + 273.16\right] + \left(u_{ztop} - u_{zbottom}\right)^2}$$

where T_{ztop} and $T_{zbottom}$ are the regressed temperatures at the top and bottom of the vertical profile in units of °C.

if $R_i > 0$ (for Stagnant/Stable IBL)
$\phi_m = \left(1 + 16R_i\right)^{0.33}$ and $\phi_p = 0.885(1 + 34R_i)^{0.4}$

if $R_i < 0$ (for Convective/Unstable IBL)
$\phi_m = \left(1 - 16R_i\right)^{-0.33}$ and $\phi_p = 0.885(1 - 22R_i)^{-0.4}$

The minimum fetch requirement that the fetch is 100 times the highest height of the air sampler for this method to be valid was not satisfied for half of the sampling periods. However, when the fetch requirement was not met, it was only slightly below the requirement (i.e. 166 m). Average fetch distances ranged from 166 to 177 m. The aerodynamic method used to estimate flux and related equations are presented in Majewski et al., 1990.

Integrated Horizontal Flux Method

The integrated horizontal flux method, also referred to as the "mass balance" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the integrated horizontal flux method, a mast is erected in the middle of the treated field and concentration samples are typically collected at four or five different heights, ranging from approximately 0.5 to 5 feet. Likewise, wind speed data are collected at a variety of heights. A log-linear regression is performed relating the natural logarithm of the sample height to the air concentration and wind speed following the log law relationships for the atmospheric boundary layer. These relationships are then incorporated into an equation to estimate flux. The methods to estimate flux and related equations are presented in Majewski et al., 1990. The equation for estimating flux using the integrated horizontal flux method is the following expression:

Equation 4 $$P = \frac{1}{x}\int_{Z_0}^{Z_p} \overline{c}\overline{u}\,dz$$

where P is the volatile flux in units of µg/m^2·s, $\overline{c}$ is the average pesticide residue concentration in units of µg/m^3 at height Z in units of meters, $\overline{u}$ is the wind speed in units of m/s at height Z, x is the fetch of the air trajectory blowing across the field in units of meters, Z_0 is the aerodynamic surface roughness length in units of meters, Z_p is the height of the plume top in units of meters, and dz is the depth of an incremental layer in units of meters. Following trapezoidal integration, equation 3 is simplified as follows in equation 5 (Yates, 1996):

Equation 5 $$P = \frac{1}{x}\sum_{Z_0}^{Z_P} (A * Ln(z) + B) * (C * Ln(z) + D)dz$$

where A is the slope of the wind speed regression line by ln(z), B is the intercept of the wind speed regression line by ln(z), C is the slope of the concentration regression by ln(z), D is the intercept of the concentration regression by ln(z), z is the height above ground level. Z_p can be determined from the following equation:

Equation 6 $$Z_P = \exp\left[\frac{(0.1 - D)}{C}\right]$$

The minimum fetch requirement of 20 meters for this method to be valid was satisfied at all times. The surface roughness length was slightly above the maximum surface roughness requirement of 0.1 meters for most monitoring periods (0.11 – 0.21), except for Period 9, when the surface roughness was 0.1.

B. Temporal Flux Profile

The flux determined from the registrant and reviewer for each sampling period after the application is provided in **Tables 6** and **7**. The pH of the tank mix was 5.59 prior to application.

Table 6. Field volatilization flux rates of dicamba obtained in study – Indirect Method

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer (µg/m²·s)	Notes	Registrant (µg/m²·s)	Notes
1	6/22/19 9:41 – 20:28	10:44	0.001392	Regression	0.001392	A
2	6/22/19-6/23/19 20:28 – 9:26	13:37	0.000283	Regression	0.000305	B
3	6/23/19-6/24/19 9:26 – 20:23	35:38	0.000257	Regression	0.000674	C, D
4	6/24/19-6/25/19 20:23 – 10:06	14:51	0.000006	Ratio of averages	0.000006	C
5	6/25/19 10:06 – 19:55	11:09	0.000000	E	0.000000	C
6	6/25/19-6/26/19 19:55 – 8:44	13:36	0.000000	E	0.000000	C
7	6/26/19 8:44 – 19:13	11:19	0.000000	E	0.000000	C
8	6/26/19-6/27/19 19:13 – 9:13	14:50	0.000000	E	0.000000	C
9	6/27/19 9:13 – 19:19	11:35	0.000126	Regression, no intercept	0.000194	B
10	6/27/19-6/28/19 19:19 – 8:42	14:21	0.000005	Regression, no intercept	0.000002	B
11	6/28/19 8:42 – 19:43	11:55	0.000325	Ratio of averages	0.000325	C
12	6/28/19-6/29/19 19:43 – 8:30	13:59	Not estimated	E	0.000017	C

Data obtained from Appendix B, Table 5, pp. 125-126 and Appendix D, Table 6, p. 559 of the study report.
Notes

- A The spatial regression method was used to calculate the flux estimate for the sampling period.
- B The sorted regression method was used to calculate the flux estimate for the sampling period.
- C The ratio method was used to calculate the flux estimate for the sampling period.
- D Due to inclement weather, one set of samples was not collected resulting in the long duration of sampling period 3. Furthermore, the samples from perimeter stations F, G, and H were collected after the other samples and had durations of 49:42, 49:45, and 49:56, respectively.
- E All measured concentrations were below the LOD. Flux rates estimated after Period 3, when the storm event occurred, are uncertain. Period 12 only had 2 concentrations that were above the LOD.

Table 7. Field volatilization flux rates of dicamba obtained in study – Integrated Horizontal Flux and Aerodynamic Methods

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer ($\mu g/m^2 \cdot s$)	Registrant ($\mu g/m^2 \cdot s$)	Empirical Flux Determination Method*	Notes
1	6/22/19 10:20 – 19:47	9:27	0.000466 0.000965	0.000897 0.000620	IHF AD	
2	6/22/19-6/23/19 19:48 – 8:53	13:05	0.000270 0.000362	0.000276 0.000370	IHF AD	
3	6/23/19-6/24/19 8:59 – 15:02	30:03	0.000068 0.000265	0.000068 0.000227	IHF AD	
4	6/24/19-6/25/19 15:04 – 9:29	18:25	0.000000 0.000000	0.000000 0.000000	IHF AD	A
5	6/25/19 8:48 – 19:11	10:23	NC NC	NC NC	IHF AD	B
6	6/25/19-6/26/19 19:16 – 8:03	12:47	0.000000 0.000000	0.000000 0.000000	IHF AD	A
7	6/26/19 8:07 – 18:22	10:15	NC NC	NC NC	IHF AD	B
8	6/26/19-6/27/19 18:25 – 7:56	13:31	0.000000 0.000000	0.000000 0.000000	IHF AD	A
9	6/27/19 7:57 – 18:26	10:29	0.000041 0.000013	0.000042 0.000005	IHF AD	
10	6/27/19-6/28/19 18:29 – 7:55	13:26	0.000014 0.000003	0.000015 0.000005	IHF AD	
11	6/28/19 7:59 – 18:05	10:06	0.000000 NC	0.000000 NC	IHF AD	C
12	6/28/19-6/29/19 18:08 – 7:47	13:39	0.000025 0.000000	0.000025 0.000000	IHF AD	

Data obtained from Appendix B, Table 5, p. 125; Appendix D, Table 8, p. 561; and Appendix D, Table 10, p. 563 of the study report.
NC indicates not calculated.
*Methods legend: AD = Aerodynamic Method, IHF = Integrated Horizontal Flux.
Notes
A All concentrations were ND or <LOD and therefore flux was assumed to be 0.000000.
B Four of five samples were <LOD, therefore flux could not be calculated.
C The concentration profile was inverted (i.e. concentrations increased with height), so flux was not estimated.

The maximum flux rate calculated by the Indirect, Integrated Horizontal Flux, and Aerodynamic methods occurred during the first sampling period after application. Study authors estimated maximum flux rates of 0.001392 $\mu g/m^2 \cdot s$, 0.000897 $\mu g/m^2 \cdot s$, and 0.000620 $\mu g/m^2 \cdot s$ for the Indirect, Integrated Horizontal Flux, and Aerodynamic methods, respectively (Appendix D, pp. 541-543). The reviewer also estimated the maximum flux rates as occurring in the first sampling period, but estimated different values for the Integrated Horizontal Flux and Aerodynamic methods. In the Integrated Horizontal Flux and Aerodynamic methods, study authors excluded the air concentration at the 1.5 m sampling height, citing them as outliers based on a deleted studentized residuals analysis. However, the reviewer included them in the analysis, as the concentrations followed the standard trend of concentrations decreasing with height and the inclusion continued to generate a good r-squared value (0.97). Likewise, for the Aerodynamic method, the regressions of temperature with height for the primary flux meteorological station were very poor (see discussion below). The reviewer used temperature data from the secondary flux meteorological station, which showed a better, more traditional fit of temperature with height.

R-squared values for the linear regressions of modeled and measured air concentrations in the indirect method ranged from 0.669 for period 1 to 0.924 for period 10. Study authors used the spatial or sorted regressions to estimate flux during periods 1, 2, 9, and 10 and the ratio method to estimate flux during periods 3, 4, 5, 6, 7, 8, 11, and 12. Flux was assumed to be 0.000000 $\mu g/m^2 \cdot s$ for periods 5, 6, 7, and 8 because no measured residues were above the LOD in these periods. For the most part, the reviewer estimated similar flux rates for all Periods except for Periods 3 and 9 when a different method was used. The reviewer did not estimate a flux rate for Period 12, as this period had only two measurable concentrations, making a regression

R-squared values in log-linear vertical profiles of wind speed were generally high with all r-squared ≥0.993 (Appendix D, Table 8, p. 561 and Appendix D, Table 10, p. 563). R-squared values in log-linear vertical profiles of concentration were low for periods 10 (0.528) and 11 (0.523).

R-squared values in log-linear vertical profiles of temperature were less than 0.7 for all periods: 1 (0.310), 2 (0.000), 3 (0.174), 4 (0.027), 5 (0.274), 6 (0.058), 7 (0.306), 8 (0.140), 9 (0.237), 10 (0.263), 11 (0.011), and 12 (0.245). The reviewer confirmed this trend, but it is unclear if the poor regressions were the result of incorrect assignment of sampling values with height. An analysis of the temperature with height using the secondary flux meteorological station indicated a good fit for temperature with height, with the r-squared values ranging from 0.49 to 0.99, with only one period below an r-squared of 0.7 (Period 4), which is when the thunderstorm occurred. As such, the reviewer used the data from the secondary flux meteorological station.

C. Spray Drift Measurements

Spray drift measurements indicated that dicamba residues were detected at a maximum fraction of the applied deposition of 0.009495 at 3 m from the field within the first hour after application (Appendix F, Table 2, pp. 639-640). Dicamba residues were detected at very low levels in the upwind samples (deposition fractions < 0.000004) and right wind samples (deposition fractions < 0.000013). **Figures 4** and **5** depict the deposition fractions and the reviewer-predicted spray drift curves for the downwind and left wind transects, respectively, within the first hour after application.

To develop the deposition curves, data were fit to a modified Morgan-Mercer-Floden function, similar to how spray drift deposition estimates were derived for the AgDRIFT, ground application model.

$$f = \frac{1}{(1 + ad)^b}$$

where f is the fraction of the application rate at distance d (m). The fitted parameters are a and b, where a is the 'slope' parameter and b is the curvature of the function. Typically, the fitted equation would include a term to account for the deposition from each swath. However, as the path of application was not always perpendicular to the deposition collectors, this term was removed from the equation. The coefficients were obtained by fitting the field data for the various transects.

Study authors derived deposition curves using four non-linear regression models for each transect (Appendix F, p. 633). For the one-hour sampling period, the best fit models were the power with coefficient model (downwind transects A and B), exponential with intercept model (downwind transect C and left wind transect A) and biexponential model (left wind transect B; Appendix F, Table 3, pp. 661-662). The curves were similar to those generated by the reviewer. Estimated distances from the edge of the field to reach NOAEC for soybeans (2.6×10^{-4} lb ae/A, or a deposition fraction of 5.2×10^{-4}) were 14.2 m (11.4 to 16.1 m for the three transects) and 11.5 m (7.7 to 14.1 m for the two transects) in the downwind and left wind directions, respectively, using the reviewer-developed curves and ranged from 9.8 to 18.2 m in the downwind direction and 14.6 to 15.3 m in the left wind direction for the study author developed curves (Appendix F, pp. 654).

Figure 4 Spray Drift Analysis for Downwind Transects – 1 Hour

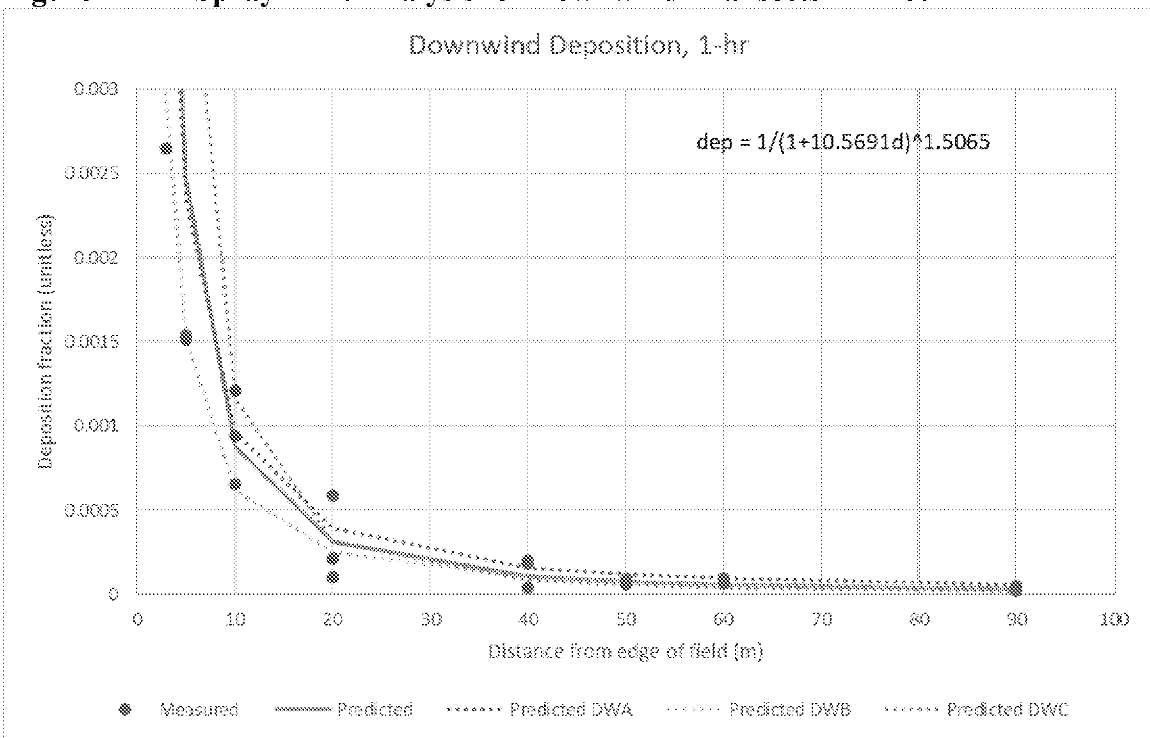
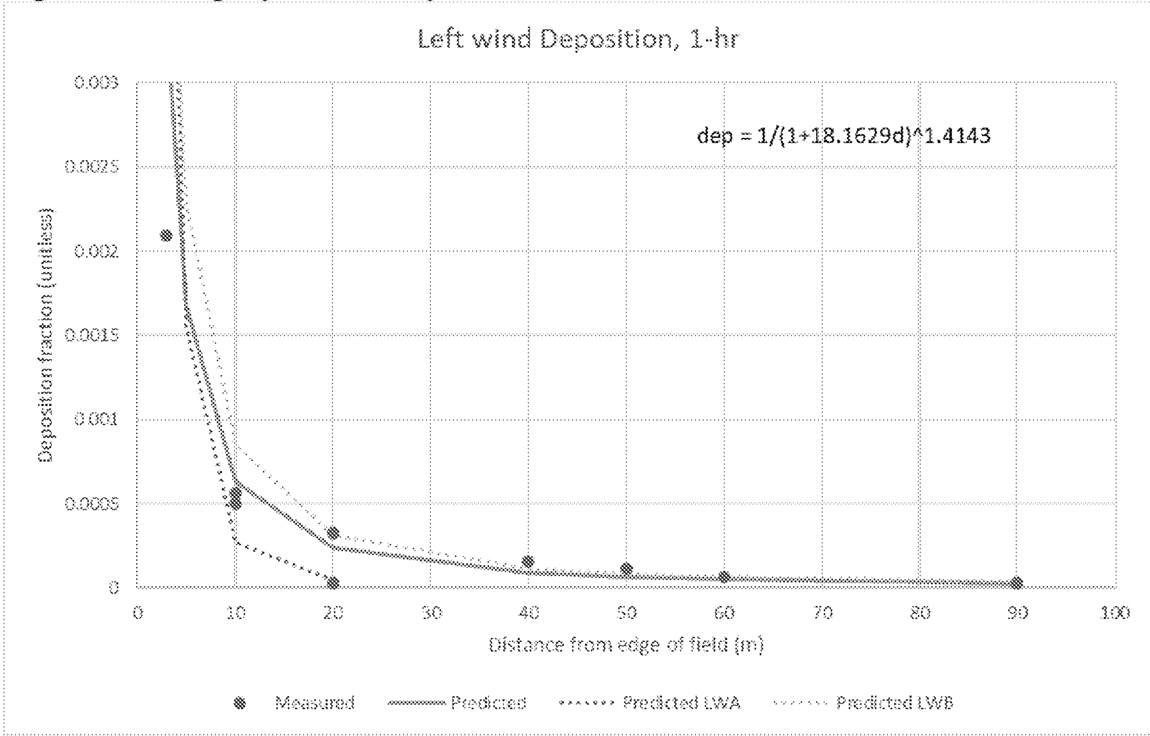


Figure 5 Spray Drift Analysis for Left wind Transects – 1 Hour



D. Plant Effects Results

Spray Drift + Volatility Exposure Transects

Plant Height

The reviewer found significant inhibitions of plant height and VSI along downwind (DW), left wind (LW) and northeast transects. The reviewer evaluated each of the observed transects independently using logistic regression methods in Excel (Figures 6, 8 & 10). The best fit regression (as indicated by the R2) for each transect were used to estimate the distance at which a 5% reduction in plant height would be predicted based on the comparison to the mean plant height from control plots. Table 8 provides distance estimates for 5% height and 10 % VSI. Maximum distance to 5% height and 10% VSI were 64 m and 112 m respectively.

Volatility Exposure (covered) Transects

Plant height measures and distances estimated with logistic regression, indicate that impacts to plant height were significantly less than observed along the uncovered transects. Effects were observed along DW, LW and UW transects with a maximum 5% height and 10% VSI effect distance estimated at >20 and 33 m respectively (Table 8). Several transects observed greater than 5% height 10%VSI across the entire transect length.

Table 8 Estimated distances to regulatory threshold responses for reductions in plant height and visible signs of injury.

Exposure Pathway	Spray Drift + Volatility (uncovered transects)		Volatility (covered transects)	
Transect	Distance to 5% Height (meters)	Distance to 10% VSI (meters)	Distance to 5% Height (meters)	Distance to 10% VSI (meters)
DWA	63.7[b]	91.0[b]	>3[d]	14.2[c]
DWB	42.5[b]	103.0[c]	>3[d]	12.6[c]
DWC	24.4[b]	60.5[b]	>20[d]	3.4[a]
LWA	>60[d]	87.3[a]	<3[d]	33.4[c]
LWB	21.3[a]	111.6[c]	<3[d]	30.1[c]
UWA	>60[d]	>60[d]	>20[d]	9.5[c]
UWB	>40[d]	>60[d]	>20[d]	3[d]
RWA	>5[d]	13.8[a]	>3[d]	<20[d]
RWB	>60[d]	2.2[a]	>20[d]	>20[d]
NE	25.7[a]	60.6[b]	NA	NA
NW	<10[d]	<3[d]	NA	NA
SE	>60[d]	>60[d]	NA	NA

[a] distance estimated with logistic regression
[b] distance estimated with polynomial regression
[c] distance estimated with linear regression
[d] distance estimated visually
NA = Not applicable

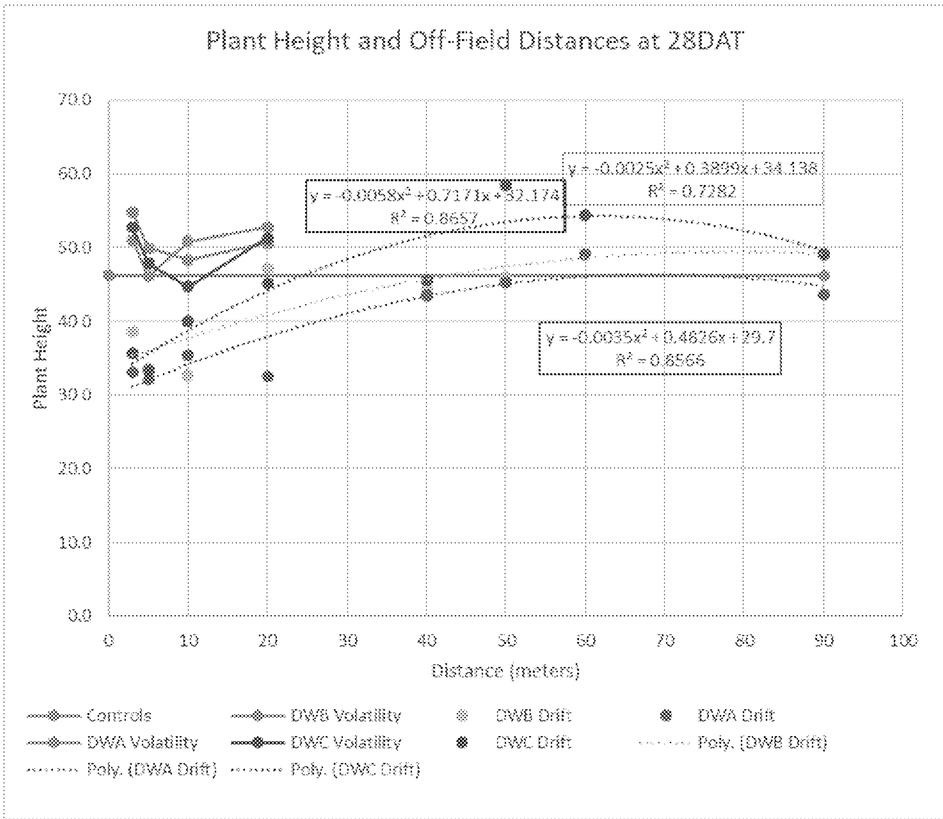


Figure 6: Regression of plant height effects at 27 days after treatment (DAT) and distance from the edge of the treated area for "Downwind Transects".

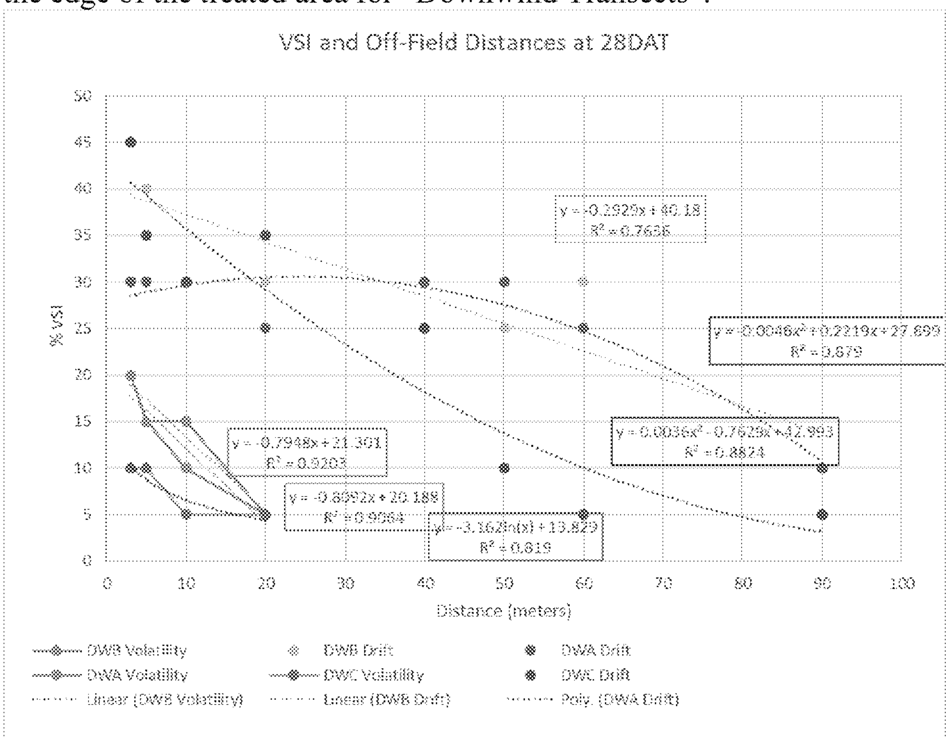


Figure 7: Regression of VSI at 27 days after treatment (DAT) and distance from the edge of the treated area for "Downwind Transects".

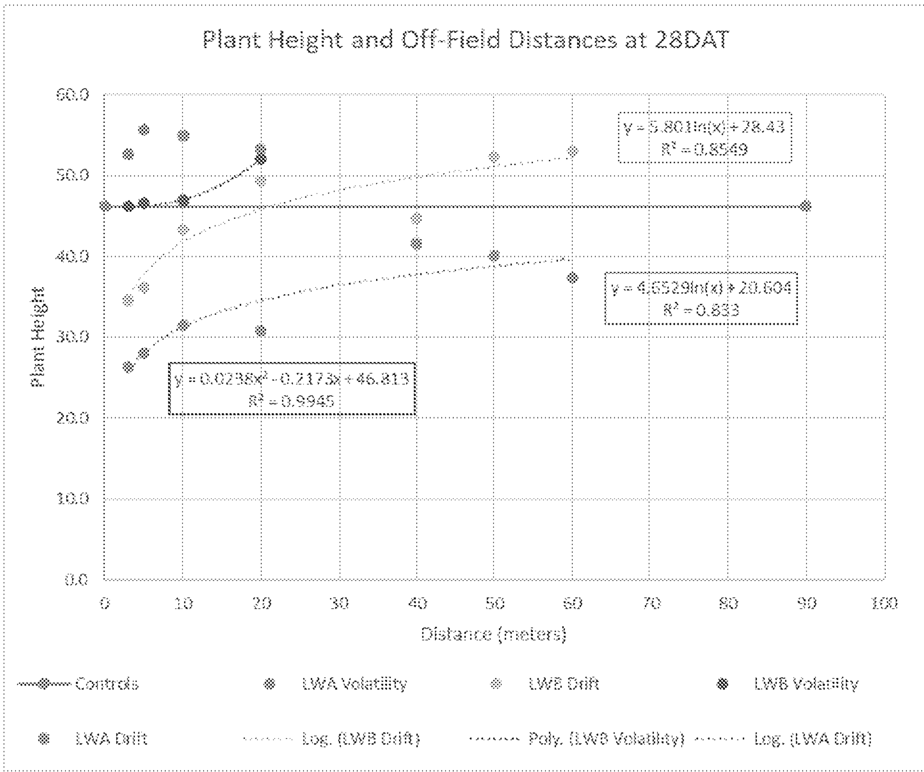


Figure 8: Regression of plant height effects at 27 days after treatment (DAT) and distance from the edge of the treated area for "Left Wind" corner transects.

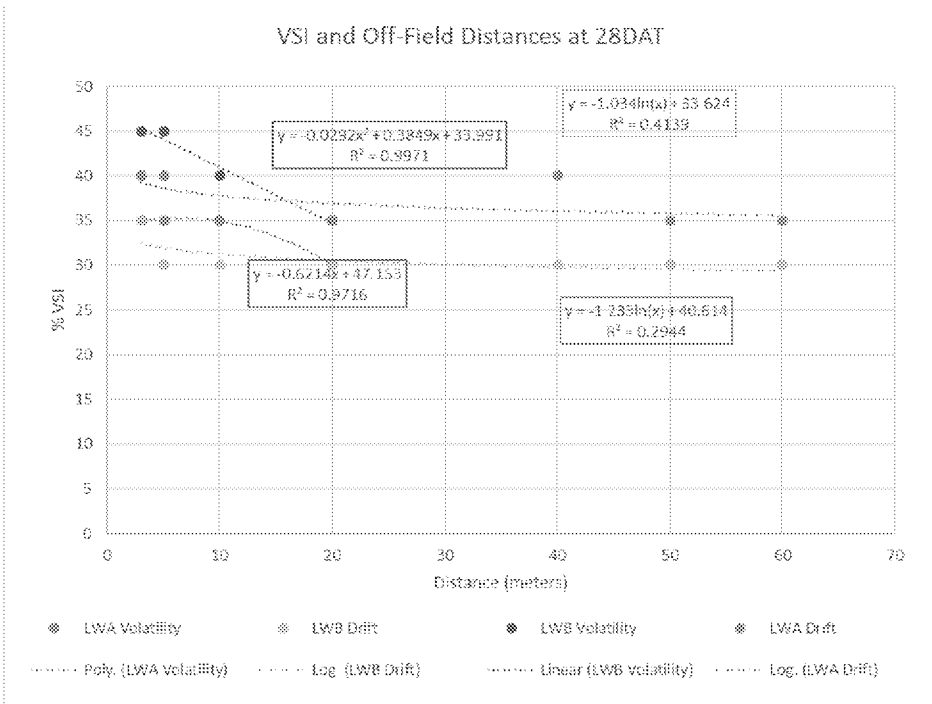


Figure 9: Regression of VSI at 27 days after treatment (DAT) and distance from the edge of the treated area for "Left Wind" transects.

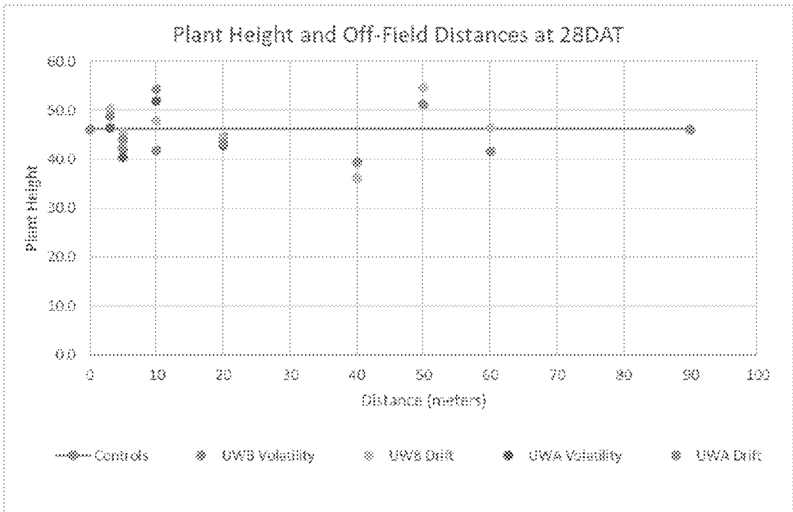


Figure 10: Regression of plant height effects at 27 days after treatment (DAT) and distance from the edge of the treated area for "Up Wind" transects.

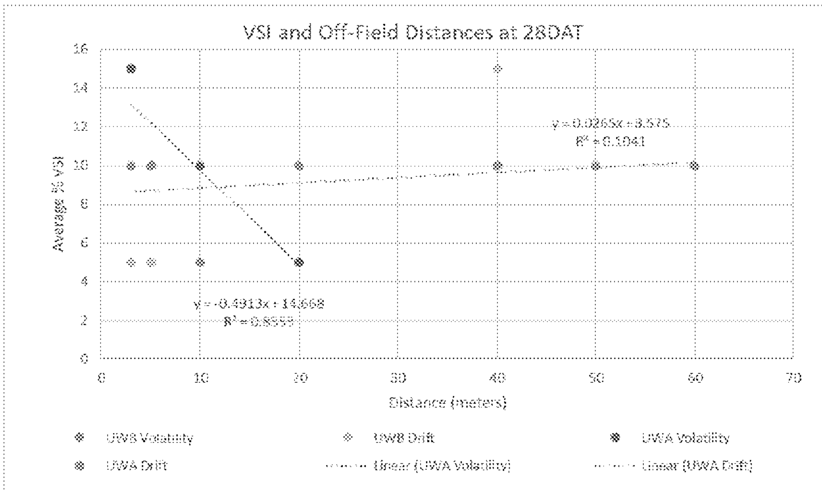


Figure 11: Regression of VSI at 27 days after treatment (DAT) and distance from the edge of the treated area for "Up Wind" transects.

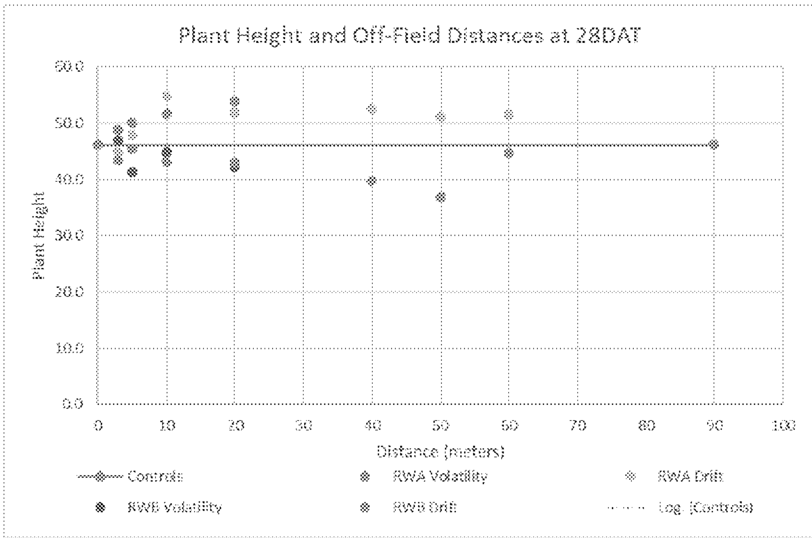


Figure 12: Regression of plant height effects at 27 days after treatment (DAT) and distance from the edge of the treated area for “Right Wind” transects.

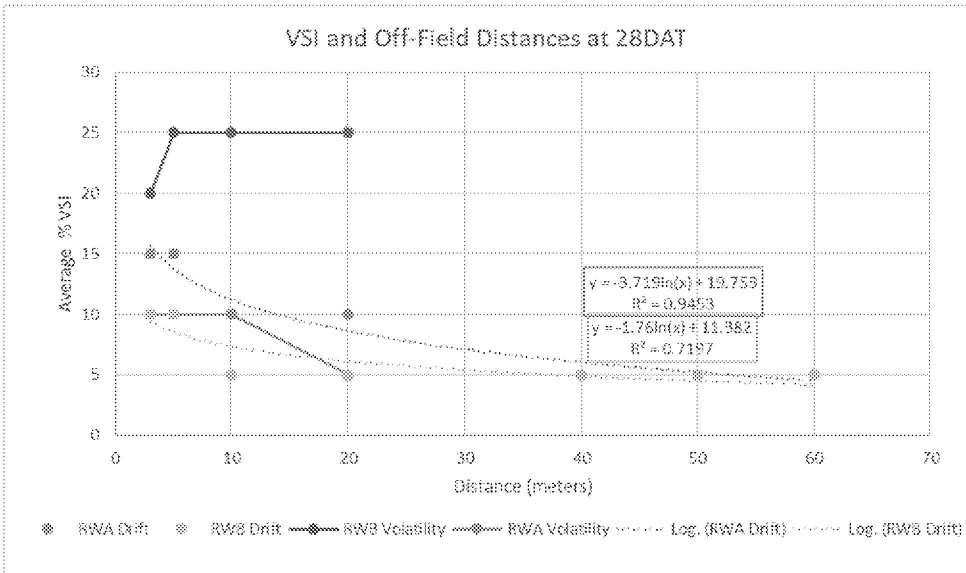


Figure 13: Regression of VSI at 27 days after treatment (DAT) and distance from the edge of the treated area for “Right Wind” transects.

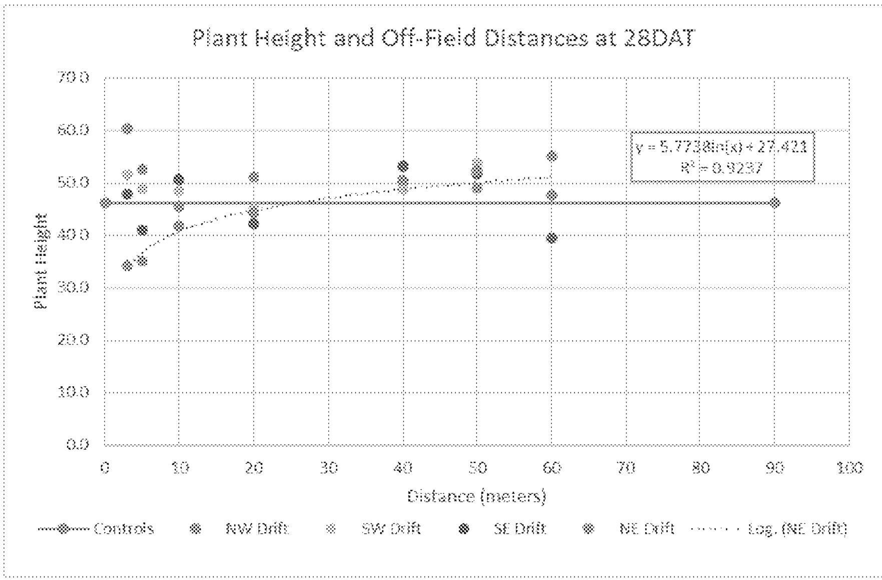


Figure 14: Regression of plant height effects at 27 days after treatment (DAT) and distance from the edge of the treated area for corner transects.

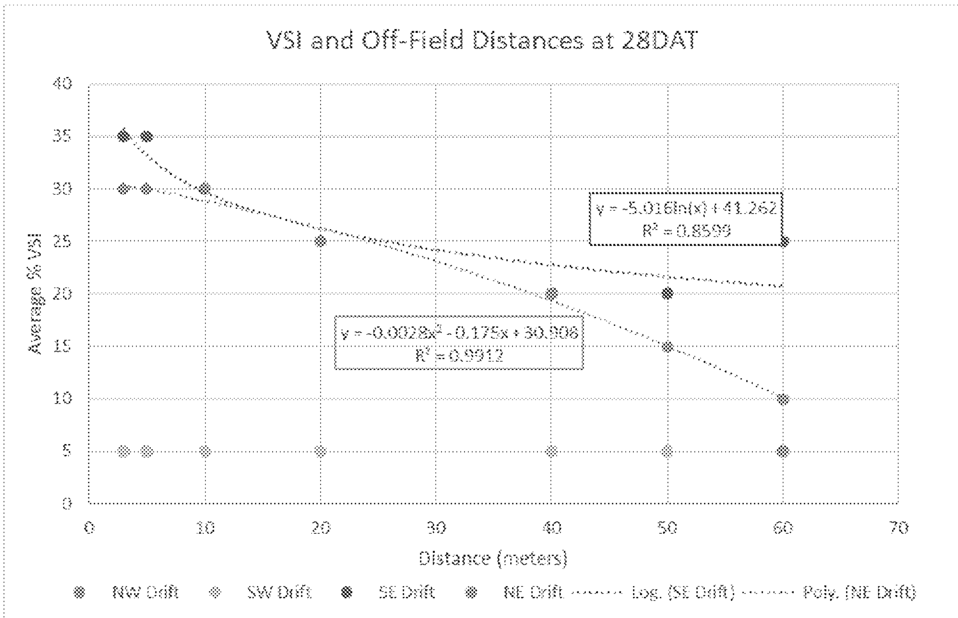


Figure 15: Regression of VSI at 27 days after treatment (DAT) and distance from the edge of the treated area for corner transects.

III. Study Deficiencies and Reviewer's Comments

1. The registrant included the use of an approved buffering agent in the tank mix, potentially to mitigate volatility. While the addition of a neutral buffering agent is permitted on the label, its use was never discussed in the submitted protocol and may have reduced the volatility one would expect to observe in an application that did not include the agent.

2. A heavy rain event delivering 4.59 inches of rain during period 3 impacted the field conditions and sampling (Appendix B, p. 116). Associated flooding prevented the deployment and collection of 36 to 48-hour and 48 to 60-hour PUF samples.

3. The registrant used a different approach to calculate Z_p, the top of the concentration plume, than that recommended by EPA when calculating volatilization flux rates using the Integrated Horizontal Flux method (Appendix D, p. 538). The registrant used:

$$Z_p = \exp\left(\frac{-D}{C}\right)$$

   C and D are the slope and intercept of the log-linear concentration regression and removed the 0.1 from the equation. The 0.1 represents the concentration at the top of the plume, which is a carryover from the use of this technique for estimating flux rates for fumigants, which typically have much higher concentrations than those anticipated for semi-volatile chemicals like dicamba. The revised equation is acceptable to the reviewer and does not significantly impact the estimate of flux rates.

4. The study was conducted in compliance with U.S. EPA Good Laboratory Practice requirements with exceptions related to test site observations, pesticide and crop history, soil taxonomy, application summary and spray rate data, and study weather data (p. 3).

5. The first air monitoring period started after the conclusion of application.

6. Analytical method validation was performed, but the method was not independently validated. A method validation study should be completed from an independent laboratory separate from and prior to the analysis of the test samples to verify the analytical methods.

7. When conducting the indirect flux rate analysis, study authors removed samples from the analysis when the dicamba was detected below the LOD (0.3 ng/PUF) for two of the sampling periods but retained samples that had no observable peak or observed residues. Samples below the LOD should be retained as well.

8. Soil was characterized (Appendix B, p. 108, and Appendix B, Table 2, p. 122), but no taxonomic classification was provided. The custom soil resource report indicated that the area was a complex of Dowling clay (7.7% of area of interest) and Sharkey clay (92.3% of area of interest; Appendix B, pp. 204-218).

9. Soil characterization (texture, bulk density and organic matter content) were reported at only a single depth of 0-6 inches (Appendix B, Table 2, p. 122).

Study Deficiencies: Plant Effects

1. A heavy rain event occurred 2 days after application and subsequently impacted growth effects due to flooding and ponding in the test fields, mostly the left wind (LW) transect. The

variable impact of the flooding on plant growth may have confounded test results. A grab sample of the flood water in the LW section resulted in dicamba concentrations detected at 0.17 mg/L in the water (Appendix G, p. 713). Bioindicator plants may have also been exposed to off-site dicamba transported in floodwater from neighboring sources(s) and/or transported in ponded water within the test field. The exact sources, concentrations and impacts were not further explored.

2. The study author calculated effects based on fit to piecewise non-linear curves, which included individual transects DWA, DWB, LWB, and NE; the study author did not report if control plant height was incorporated in this modeling. The reviewer analyzed the entire height data set for each transect and compared data to plants in the control field.

3. The Syngenta NK S45-W9 variety of soybean that was planted in the test plots for both the volatility and spray drift study, is a non-Dicamba tolerant soybean. This variety was also selected because of its glyphosate-tolerance. It is uncertain if this genetically modified variety may have impacted dicamba effects compared to a non-genetically modified variety.

4. Following application for both the volatility and spray drift portions of the study, the study author notes that, "Plants were selected non-systematically with no attempt to measure the same plant during subsequent sampling events" (Appendix G, p. 709).

   OCSPP guidance recommends that the integrity of the replicate should be maintained throughout the duration of the study. In this study, plant height was determined for ten different plants at slightly different distances at each sampling interval. The reviewer suggests that this sampling method is inadequate and introduces unnecessary variability into the study results that should have been more systematically controlled.

5. Transects, except the downwind drift transect, totaled 10-20 plants for analysis per distance instead of 30 overall as recommended by OCSPP guidance.

6. The study author did not provide historical germination rates for the soybean varieties planted.

7. Test plots contained clay soils. OCSPP guidance states clay soils should not be used if the test substance is known to have a high affinity for clay.

8. The control plot was placed upwind of the treatment field. The specific distance upwind from the edge of the field was not reported.

9. Pesticides applications to the treatment field and test plots in 2019 were not reported.

10. The physico-chemical properties of the test material were not reported.

IV. References

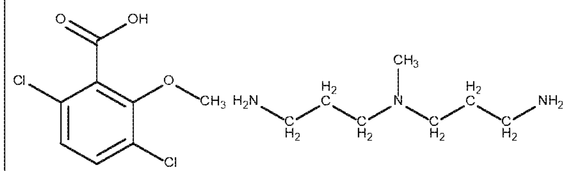
Gavlick, W. (2016). *Determination of a No Effect Crop Response as a Function of Dicamba Vapor Concentration in a Closed Dome System*. Monsanto Company. MSL0028204.

US EPA. (1998). *Spray Drift Test Guidelines, OPPTS 840.1200 Spray Drift Field Deposition*. United States Environmental Protection Agency, Prevention, Pesticides, and Toxic Substances. EPA 712-C-98-112.

US EPA. (2012). *Field Volatility Study Review Guide*. United States Environmental Protection Agency.

US EPA (2013). *Data Evaluation Report on the Toxicity of Clarity 4.0 SL (AI: Dicamba) to Terrestrial Vascular Plants: Vegetative Vigor*. United States Environmental Protection Agency, Washington D.C. MRID 47815102.

DER ATTACHMENT 1. Dicamba BAPMA and Its Environmental Transformation Products. [A]

Code Name/ Synonym	Chemical Name	Chemical Structure	Study Type	MRID	Maximum %AR (day)	Final %AR (study length)
PARENT						
Dicamba BAPMA (N,N-Bis-(3-aminopropyl)methylamine salt of dicamba; BAS 183 22 H; Dicamba-biproamine)	**IUPAC:** 3,6-Dichloro-o-anisic acid - N-(3-aminopropyl)-N-methylpropane-1,3-diamine (1:1) **CAS:** 3,6-Dichloro-2-methoxybenzoic acid compound with N1-(3-aminopropyl)-N1-methyl-1,3-propanediamine (1:1) **CAS No.:** 1286239-22-2 **Formula:** $C_{15}H_{25}Cl_2N_3O_3$ **MW:** 366.28 g/mol **SMILES:** NCCCN(C)CCCN.ClC1=CC=C(Cl)C(C(O)=O)=C1OC		835.8100 Field volatility	51049002 51049003 51049004	NA	NA
MAJOR (>10%) TRANSFORMATION PRODUCTS						
No major transformation products were identified.						
MINOR (<10%) TRANSFORMATION PRODUCTS						
No minor transformation products were identified.						
REFERENCE COMPOUNDS NOT IDENTIFIED						
All compounds used as reference compounds were identified.						

[A] AR means "applied radioactivity". MW means "molecular weight". NA means "not applicable".

ED_005172C_00001171-00034

Attachment 2: Statistics Spreadsheets and Graphs

Supporting spreadsheet files accompany the review.

1. Air sampling periods and soil temperature and moisture graphs

   100094_51049003_DE
   R-FATE_835.8100_5-04

2. Validation spreadsheet for the Indirect Method

   100094_51049003_DE
   R-FATE_835.8100_5-04

3. Validation spreadsheet for the Integrated Horizontal Flux Method:

   100094_51049003_DE
   R-FATE_835.8100_5-04

4. Validation spreadsheet for the Aerodynamic Method:

   100094_51049003_DE
   R-FATE_835.8100_5-04

5. Air modeling files

   10094_51049003
   modeling files.zip

6. Validation spreadsheet for spray drift calculations

   100094_51049003_DE
   R-FATE_840.1200_8-29

7. Terrestrial Plants: Vegetative Vigor. MRID 51049003, EPA Guideline 850.4150

   Folder: 100094 51049003 850.4150

Attachment 3: Field Volatility Study Design and Plot Map

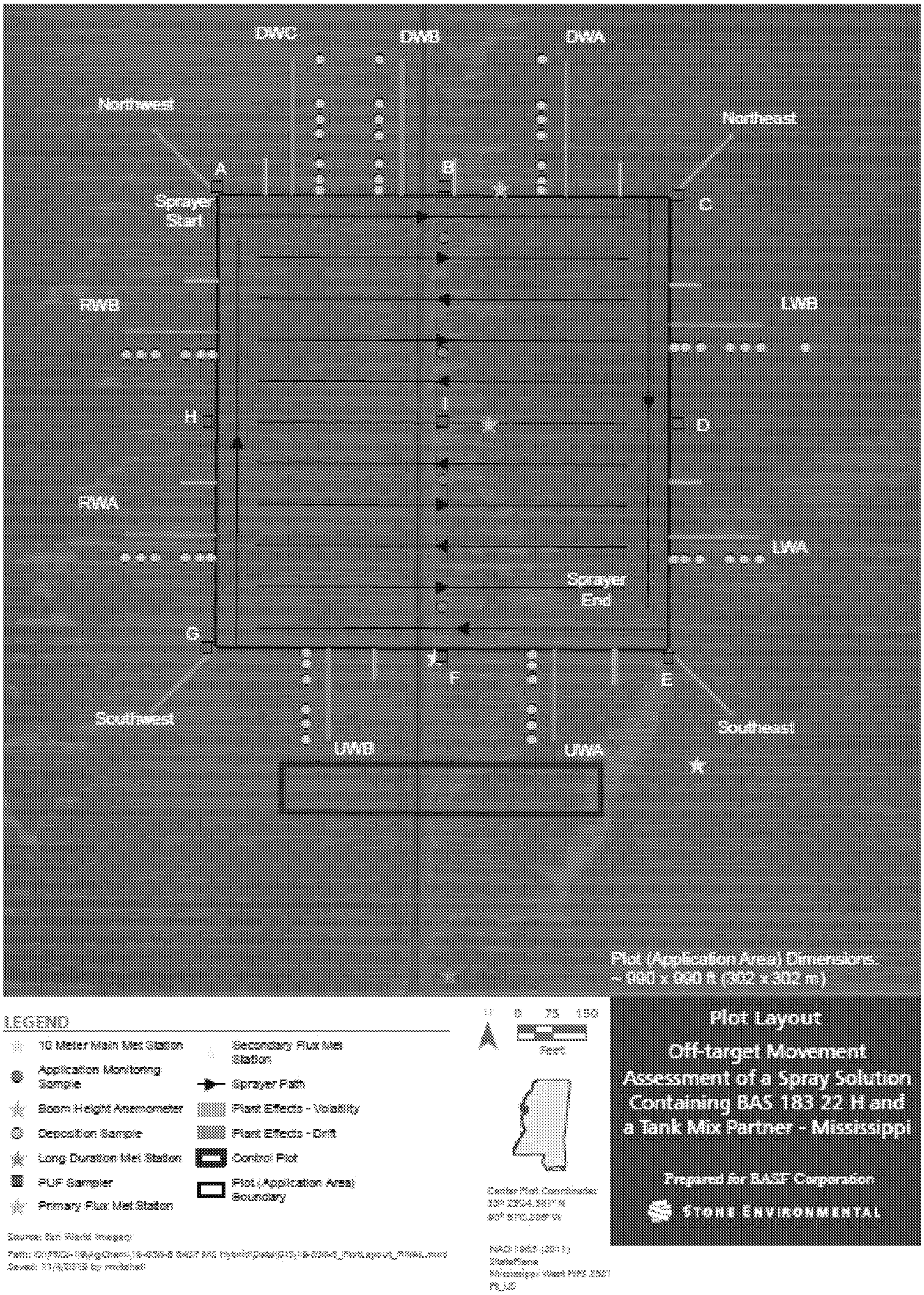


Figure obtained from Appendix B, Figure 3, p. 142 of the study report.